

What is claimed is:

4p
a14
1. A billet of steel for continuous cold forging, characterized by 0.46 - 0.48 wt % of C (carbon), 0.14 or less of Si (silicon), 0.55 - 0.65 wt % of Mn (manganese), 0.015 wt % or less of P (phosphorus), 0.015 wt % or less of S (sulfur), 0.15 wt % or less of Cu (copper), 0.20 wt % or less of Ni (nickel), and 0.35 wt % or less of Cr (chromium).

2. A billet according to claim 1, characterized in that a carbide of the billet has an aspect ratio of 300 % or less.

3. A billet according to claim 1, characterized by having a limiting upsetting ratio of 90 % or more.

4. A method of manufacturing a billet for cold forging, characterized by the first spherodizing annealing step of spherodizing a carbide in a blank, the drawing step of drawing the blank at a predetermined sectional area reduction ratio after the first spherodizing annealing step, and the second spherodizing annealing step of promoting the dispersion of the internal carbide

for an increased spherodizing ratio after the drawing step.

5. A method according to claim 4, characterized in that said drawing step has a drawing ratio of approximately 20 %.

6. A method according to claim 4, characterized in that said blank is cut to a desired dimension between said first spherodizing annealing step and said second spherodizing annealing step.

7. A method according to claim 4, characterized in that said blank is composed of 0.46 - 0.48 wt % of C (carbon), 0.14 or less of Si (silicon), 0.55 - 0.65 wt % of Mn (manganese), 0.015 wt % or less of P (phosphorus), 0.015 wt % or less of S (sulfur), 0.15 wt % or less of Cu (copper), 0.20 wt % or less of Ni (nickel), and 0.35 wt % or less of Cr (chromium).

8. A method of manufacturing a billet for cold forging, characterized by the steps of quenching a blank unloaded from a heating furnace to form a fine martensitic structure in a surface thereof, and then annealing the blank to convert the martensitic structure of the

surface into a fine spherodized structure comprising ferrite and cementite.

9. A method according to claim 8, characterized in that said blank is annealed by holding the blank at about 740°C for 6 hours, thereafter dropping the temperature to about 680°C at a rate of 20°C/h, and thereafter cooling the blank in a furnace.

10. A method according to claim 8, characterized in that said blank is annealed by holding the blank at about 750°C for 4 hours, then at about 735°C for 3.5 hours, thereafter dropping the temperature to about 680°C at a rate of 15°C/h, and thereafter cooling the blank in a furnace.

11. A method according to any one of claims 8 through 10, characterized in that said blank is made of a carbon steel which is composed of 0.46 - 0.48 wt % of C (carbon), 0.14 or less of Si (silicon), 0.55 - 0.65 wt % of Mn (manganese), 0.015 wt % or less of P (phosphorus), 0.015 wt % or less of S (sulfur), 0.15 wt % or less of Cu (copper), 0.20 wt % or less of Ni (nickel), 0.35 wt % or less of Cr (chromium), and a remainder of Fe (iron) and impurities.

12. A method of cold-forging a billet manufactured by a method according to any one of claims 8 through 11, characterized by the steps of cold-forging the billet for by continuously drawing the billet, upsetting the billet, and finishing the billet without softening the billet in an intermediate stage.

13. A method according to claim 12, characterized by being applied to the manufacture of a crankshaft.

14. A method of cold-forging a crankshaft from a billet formed by continuous cold forging, characterized by the first step of extruding the billet to form a multi-stepped shaft having at least two steps and contiguous to a main body, the second step of upsetting and drawing the formed workpiece to simultaneously increase the diameter of the main body and reduce the diameter of at least a portion of the multi-stepped shaft, the third step of upsetting and drawing the formed workpiece to simultaneously rough the main body to an asymmetrical shape and reduce the diameter of at least a portion of the multi-stepped shaft, the fourth step of pressing an asymmetrical boundary of the main body to simultaneously finish the main body and form a central hole axially centrally in the main body, and the fifth step of forming a pin hole in the main body at a predetermined position and

7

removing an outer circumferential portion of the main body thereby to shape the main body.

15. A method according to claim 14, characterized in that splines are formed on an end of said multi-stepped shaft in said fourth step.

16. A method of cold-forging a disk-shaped part with a shaft from a multi-stepped intermediate blank through a plurality of forging steps, characterized by forming an asymmetrical disk having left and right portions of different volumes with respect to an axial center of said intermediate blank.

17. A method according to claim 16, characterized in that the ratio of the volumes of the left and right portions of said disk is about 1 : 2.

18. A method according to claim 16 or 17, characterized in that in order to achieve the different volumes, inclined surfaces having different angles of inclination are formed across a junction between the left and right portions which extends from the shaft of the blank to the disk.

19. A method according to claim 18, wherein the angle of inclination of the portion having the greater volume is smaller than the angle of inclination of the portion having the smaller volume.

20. A method of cold-forging a crankshaft, characterized by continuously cold-forging a blank made of a carbon steel which is composed of 0.46 - 0.48 wt % of C (carbon), 0.14 or less of Si (silicon), 0.55 - 0.65 wt % of Mn (manganese), 0.015 wt % or less of P (phosphorus), 0.015 wt % or less of S (sulfur), 0.15 wt % or less of Cu (copper), 0.20 wt % or less of Ni (nickel), 0.35 wt % or less of Cr (chromium), and a remainder of Fe (iron) and impurities, thereby to produce a crankshaft, and thereafter aging the crankshaft.

21. A method of cold-forging a crankshaft, characterized by the first spherodizing annealing step of spherodizing a blank made of a carbon steel which is composed of 0.46 - 0.48 wt % of C (carbon), 0.14 or less of Si (silicon), 0.55 - 0.65 wt % of Mn (manganese), 0.015 wt % or less of P (phosphorus), 0.015 wt % or less of S (sulfur), 0.15 wt % or less of Cu (copper), 0.20 wt % or less of Ni (nickel), 0.35 wt % or less of Cr (chromium), and a remainder of Fe (iron) and impurities, the drawing step of drawing the blank at a predetermined sectional

area reduction ratio after the first spherodizing annealing step, the second spherodizing annealing step of promoting the dispersion of an internal carbide for an increased spherodizing ratio after the drawing step thereby to produce a billet, continuously cold-forging the billet into a crankshaft, and thereafter aging the crankshaft.

22. A method according to claim 20 or 21, characterized in that the crankshaft is aged by holding the crankshaft at a temperature ranging from 250 to 350°C for 1 to 2.5 hours, and thereafter cooling the crankshaft to normal temperature.

23. A method of cold-forging a disk-shaped part with a shaft, characterized by holding the shaft of the cold-forged disk-shaped part with a lower support base of a forming die, lowering an upper die assembly to hold the disk of the disk-shaped part between the lower support base and an upper support base and lower the disk-shaped part by a predetermined stroke, punching a hole in a predetermined region of the disk with a punch of a lower die assembly, and thereafter lowering the upper die assembly to cause an upper die to remove an outer circumferential portion of the disk.

24. A method according to claim 23, characterized by accommodating a scrap removed by the punch in a receptacle in the upper support base, holding a scrap removed by the upper die between the lower die assembly and the upper die, and thereafter, when the upper die assembly is lifted, placing the scraps into original positions thereof in the disk, and discharging the scraps when the disk-shaped part is ejected.

25. A forming die apparatus for simultaneously forming a hole in a predetermined region of a disk of a disk-shaped part with a shaft which has been cold-forged, and removing an outer circumferential portion of the disk, characterized by a lower support base vertically movable by a predetermined stroke for holding the shaft of the disk-shaped part, a punch fixed to a lower die assembly, an upper support base for holding the disk of the disk-shaped part in coaction with the lower die assembly in response to downward movement of the upper die assembly, and an upper die vertically movable with respect to said upper support base, the arrangement being such that while the disk-shaped part with the shaft is being lowered the predetermined stroke upon downward movement of the upper die assembly, a hole is formed in the disk by the punch, and upon further downward movement of the upper die assembly, the downward movement of the disk-

shaped part with the shaft stops and the outer circumferential portion of the disk is removed by the upper die.

26. A cold-forging die apparatus for upsetting a blank for cold forging between a punch and a die, characterized in that said punch has a nib and a reinforcing ring fitted around said nib, said nib being split into an inner nib and an outer nib which are held in interfitting relationship to each other, by a split surface which is located in the vicinity of a boundary between a region where radial stresses mainly act and a region where axial stresses mainly act when the blank is upset.

27. A cold-forging die apparatus according to claim 26, characterized in that the inner nib where axial stresses mainly act when the blank is upset has an axial dimension selected such that the inner nib projects axially beyond the outer nib, in view of an axial deformation caused when the blank is upset.

28. A cold-forging die apparatus according to claim 26, characterized in that the cold-forging die apparatus is used to form a counterweight of a crankshaft.



Table 1:

| | Billet manufacturing process | | | | | Aspect ratio of carbide (%) | Crack percentage % N=100 |
|------------|---|------------|---------|--|------------------|-----------------------------|--------------------------|
| | Spherodizing annealing prior to drawing | Drawing | Cutting | Spherodizing annealing subsequent to drawing | Shot bonderizing | | |
| Material 1 | None | None | ○ | ○ | ○ | 506 | 35% |
| Material 2 | None | (20%) ○ | ○ | ○ | ○ | 347 | 5% |
| Material 3 | ○ | (20%) ○ | ○ | ○ | ○ | 300 | 0% |

$$\text{Aspect ratio (\%)} = b/a \times 100$$

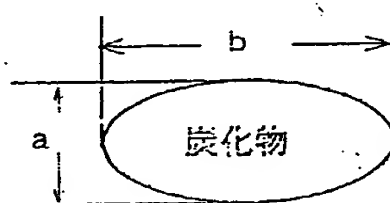




Table 2:

| | C | Si | Mn | P | S | Cu | Ni | Cr | Crack percentage (N=100) |
|-------------------------------------|-----------|-----------------|-----------|------------------|------------------|-----------------|-----------------|-----------------|--------------------------------|
| JIS S48C | 0.45~0.51 | 0.15~0.35 | 0.60~0.90 | 0.03 or less | 0.035 or less | 0.30 or less | 0.20 or less | 0.35 or less | 20% |
| Mn reduced | ↑ | ↑ | 0.55~0.65 | ↑ | ↑ | ↑ | ↑ | ↑ | 12% |
| Mn, C reduced | 0.45~0.48 | ↑ | 0.55~0.65 | ↑ | ↑ | ↑ | ↑ | ↑ | 5% |
| Mn, C reduced Inclusions reduced | 0.45~0.48 | 0.14 or less | 0.55~0.65 | 0.015 or less | 0.015 or less | 0.15 or less | ↑ | ↑ | 0% |

Table 3:



| Material | Process | Crack confirmation test | |
|---|---|-------------------------|----------------------|
| | | Upsetting test | Crankshaft formation |
| R material | Cutting→Acid pickling→Spherodizing annealing →Shot blasting +Bonderizing | 8/10=80% | 10/10=100% |
| Controlled rolling material | Cutting→Acid pickling→Spherodizing annealing →Shot blasting +Bonderizing | 5/25=20% | 2/30=7% |
| R material | Acid pickling→Spherodizing annealing→Acid pickling, Bonderizing→Drawing, Acid pickling→Spherodizing annealing→Shot blasting+Bonderizing | 0/30=0% | 0/30=0% |
| Controlled rolling material | Acid pickling→Spherodizing annealing→Acid pickling, Bonderizing→Drawing, Acid pickling→Spherodizing annealing→Shot blasting+Bonderizing | 0/30=0% | 0/30=0% |
| Surface-hardened steel (present invention) | Cutting→Acid pickling→Spherodizing annealing →Shot blasting+Bonderizing | 0/20=0% | 0/30=0% |



Table 4

| Component | C | | Mn | P | S | Cu | Ni | Cr |
|----------------------|-----------|-----------------|-----------|------------------|------------------|-----------------|----------------|-----------------|
| Proportion (wt %) | 0.46~0.48 | 0.14 or less | 0.55~0.65 | 0.015 or less | 0.015 or less | 0.15 or less | 0.2 or less | 0.35 or less |

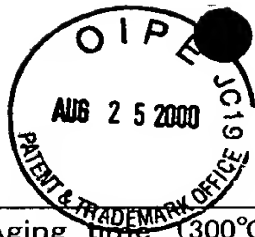


Table 5:

| No | Aging time (300°C) |
|----|--------------------|
| A | No aging |
| B | 0.5H |
| C | 1.0H |
| D | 1.5H |
| E | 2.0H |
| F | 2.5H |
| G | 4.0H(Over Aging) |

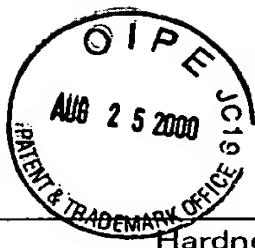


Table 6:

| No | Hardness(HRC) | | | d value (A) |
|----|---------------|-------------|------------|-------------|
| | Before aging | After aging | (Internal) | |
| A | 23.3 | | | 2.0291 |
| B | 22.8 | 23.1 | 23.7 | 2.0300 |
| C | 23.4 | 23.6 | 24.5 | 2.0308 |
| D | 23.2 | 23.8 | 24.8 | 2.0308 |
| E | 23.4 | 23.9 | 24.5 | 2.0317 |
| F | 22.9 | 23.8 | 24.7 | 2.0300 |
| G | 23.4 | 23.7 | 24.4 | 2.0308 |

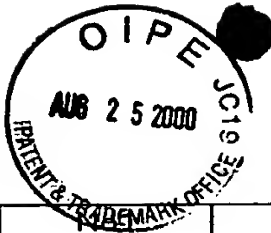


Table 7:

| Point | | No2 | No3 |
|---------|------|------|------|
| 1 | 23.9 | 23.5 | 23.4 |
| 2 | 23.4 | 23.4 | 23.8 |
| 3 | 23.7 | 23.0 | 23.2 |
| 4 | 23.5 | 23.4 | 23.4 |
| Average | 23.6 | 23.3 | 23.4 |

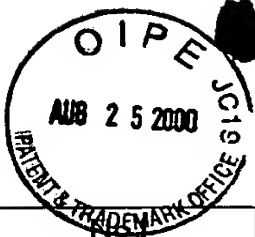


Table 8:

| Point | | | No2 | | No3 | |
|---------|---------|----------|---------|----------|---------|----------|
| | Surface | Internal | Surface | Internal | Surface | Internal |
| ① | 24.1 | 25.4 | 26.4 | 22.5 | 26.6 | 22.4 |
| ② | — | 27.8 | — | 24.6 | — | 23.4 |
| ③ | 25.4 | 26.0 | 25.5 | 25.4 | 25.7 | 25.9 |
| ④ | 23.5 | 24.6 | 23.6 | 25.2 | 22.9 | 24.6 |
| ⑤ | 23.8 | 25.4 | 22.8 | 25.2 | 23.6 | 25.6 |
| ⑥ | 23.1 | 25.4 | 23.8 | 25.0 | 24.2 | 25.7 |
| ⑦ | 23.2 | 25.7 | 23.3 | 25.2 | 23.4 | 25.6 |
| Average | 23.9 | 25.8 | 24.2 | 24.7 | 24.4 | 24.7 |